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ABSTRACT

Radioisotopes are useful because of their three unique characteristics: (1) radiation emission; (2) predictable radioactive lives; and (3) the same chemical properties as the nonradioactive atoms of that element. Researchers are able to "order" a radioisotope with the right radiation, half-life, and chemical property to perform a given task with the knowledge of these three characteristics. This publication includes information on the uses of radioisotopes in medicine for providing doctors with diagnostic and therapeutic techniques for scanning organs and contributing to the healing process in the treatment of cancer. Radioisotopes can help to authenticate works of art and solve crimes. In industry radioisotopes are used to detect hidden flaws in hardware and improve product quality. Uses in agriculture include insect control and the preservation of foods. (RT)

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Nuclear Energy

RADIOISOTOPES: Today's Applications

ED 297951

SE049 429

U.S. Department of Energy
Assistant Secretary for
Nuclear Energy
Office of Program Support

RADIOISOTOPES: TODAY'S APPLICATIONS

In the century since they were first discovered, radioisotopes have transformed the fields of medicine, science, industry, and agriculture. Radioisotopes have become the powerful and often subtle tools that researchers now rely on to probe and unravel nature's most closely guarded secrets.

Doctors look deep into the hidden recesses of the human body without scalpel or pain, observing the delicate functions of internal organs to detect and treat disease in its early stages. Scientists chart the lost chronology of the ancient past, precisely dating the era of delicate fossil fragments and ancient mountain ranges. Manufacturers produce metal castings that are free from flaws and plastics with unprecedented strength. Farmers use less fertilizer yet grow crops with higher yields to help feed a hungry world.

For more detailed information about the unique characteristics of radioisotopes, open cover flap.

ABOUT RADIATION AND RADIOISOTOPES...

Atoms that emit radiation are called radioactive isotopes or *radioisotopes*. There are radioisotopes of most of the chemical elements on Earth. Many occur naturally; many more can be manmade. A radioisotope is designated by a name and a number. The name is that of the chemical element, and the number is its atomic weight. For instance, the radioisotope carbon-14 has the same chemical properties as the stable element carbon-12 but is heavier by two atomic weight units. The difference in weight, in this case, makes carbon-14 radioactive.

Radioisotopes have three unique characteristics that make them useful tools:

- **Radioisotopes emit radiation.**

Radiation, in the form of rays or particles, can penetrate substances of varying thicknesses such as paper, body tissue, or concrete. The rays, called *gamma rays*, can be extremely energetic but can be stopped by about four feet of concrete. The particles, on the other hand, have less penetrating power. A thin sheet of metal will stop a *beta particle*, which is really an electron. A single sheet of paper will stop an *alpha particle*, which is very much larger than a beta particle.

- **Radioisotopes have radioactive lives that are predictable.**

Over time, radioisotopes lose their radioactivity through the process of radioactive decay that is measured in *half-lives*. The half-life of a radioactive substance is the time it takes for a quantity of that substance to lose one-half its radioactivity. Half-lives of radioisotopes range from fractions of a second to millions of years, but the half-life of each radioisotope is precisely known.

- **Radioisotopes of a chemical element have the same chemical properties as the nonradioactive atoms of that element.**

Radioisotopes are available that have the chemical properties of nearly all the known chemical elements on Earth, making it possible to trace a chemical element by adding a radioisotope of that element. Radioisotopes used in this way are sometimes referred to as *radiotracers*.

Knowledge of these three characteristics enables researchers to "order" a radioisotope with just the right radiation, half-life, and chemical property to perform a given task.

RADIOISOTOPES IN MEDICINE

In the field of medicine, radioisotopes have far exceeded the promise that researchers first saw in them. All major hospitals now have entire departments dedicated to nuclear medicine. Today, about one-half of all patients admitted to U.S. hospitals are diagnosed or treated using radioisotopes. Diagnostic techniques using radioisotopes have given a new dimension to the word "scan." Doctors routinely use radioisotopes to scan organs and follow blood flow in the body. Radioisotopes also contribute to the healing process, particularly in the treatment of cancer.

Diagnostic Applications

Radioisotopes provide doctors with powerful tools to peer inside the human body, giving them a new vision. Instead of relying on x rays, doctors can now use the radiation given off by certain radioisotopes to take pictures of the internal workings of the body. To do this, a radioisotope is concentrated in an organ, such as the heart or the brain, and an external camera, sensitive to the emitted radiation, produces an image of the organ. Imaging an organ with a radioisotope is called *single photon emission computed tomography* (SPECT), and the process is called a SPECT scan.

Some elements concentrate naturally in certain parts of the body—iodine in the thyroid, phosphorus in the bones, potassium in the muscles, and so on. For this reason, doctors can use radioisotopes of these elements for certain types of procedures. If the required radioisotope

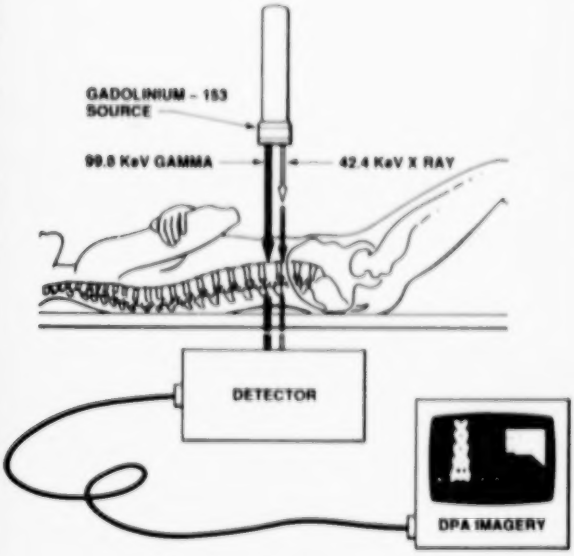
Radiation given off by radioisotopes permits external cameras to take pictures of internal organs of the body for medical diagnosis.

does not concentrate naturally in the organ under study, a radioisotope can be chemically attached to a compound that will carry it to the organ so that a picture can be taken. This process of attaching a radioisotope to a chemical compound is called *labeling*, and the procedure has greatly expanded the diagnostic applications of radioisotopes.

With technetium-99m, now the most widely used radioisotope for diagnosis, doctors examine the brain, heart, blood, lungs, liver, kidneys, thyroid, spleen, and bone. For example, the loss of calcium in older people, especially women, can lead to weakened bones and a condition called *osteoporosis*. To diagnose the condition, doctors can view a patient's skeleton by injecting technetium-99m into the blood in a chemical form that concentrates in

the bones. From pictures taken by a sensitive camera, doctors diagnose the condition of the bones and prescribe treatment. A new method of diagnosing osteoporosis uses gadolinium-153. This radioisotope emits two soft gamma rays that differ widely in energy. When the gamma rays are focused on the skeletal structure, the difference in energy permits the bone disease to be identified. The method is called *dual photon absorptiometry* (DPA).

Doctors are currently using two radioisotopes to diagnose heart disease: thallium-201 and technetium-99m. These radioisotopes are used as blood flow markers, allowing doctors to detect the risk of heart disease. Doctors inject one of

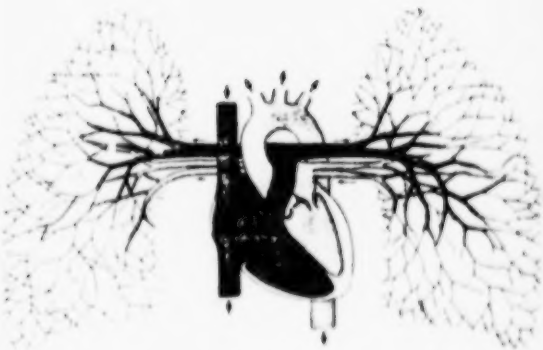


DUAL PHOTON ABSORPTIOMETRY

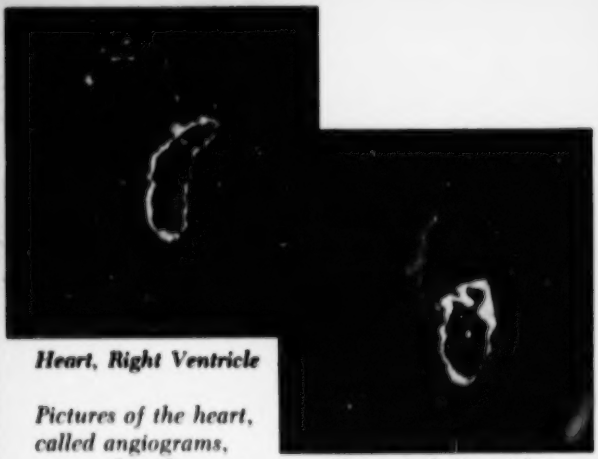
The technique of dual photon absorptiometry, which relies on the radioisotope gadolinium-153, enables physicians to make early diagnosis of osteoporosis.

the radioisotopes into the patient's blood during exercise on a treadmill. The radioisotope concentrates in the heart, allowing doctors to follow the blood flow. Looking at an image of the heart, doctors can detect the reduced blood flow through the arteries that feed it, which can signal heart disease. Technetium-99m is being used increasingly because it has a shorter half-life than thallium-201 (6 hours as opposed to 72), thus reducing the amount of radiation a patient receives.

Radioisotopes, such as carbon-11 or fluorine-18, provide another method of looking at internal organs. These radioisotopes emit positively charged beta particles, called *positrons*, and pairs of gamma rays traveling in opposite directions. Two moveable cameras, placed opposite each other, detect the rays and permit a three-dimensional image to be constructed by a computer. The technique



Obstruction to blood flow in the heart can be detected through the use of radioisotopes.



Heart, Right Ventricle

Heart, Left Ventricle

Pictures of the heart, called angiograms, are used to diagnose heart disease. Radioisotopes such as irridium-191m allow doctors to determine the condition of the heart. (Courtesy of Belgian collaborators)

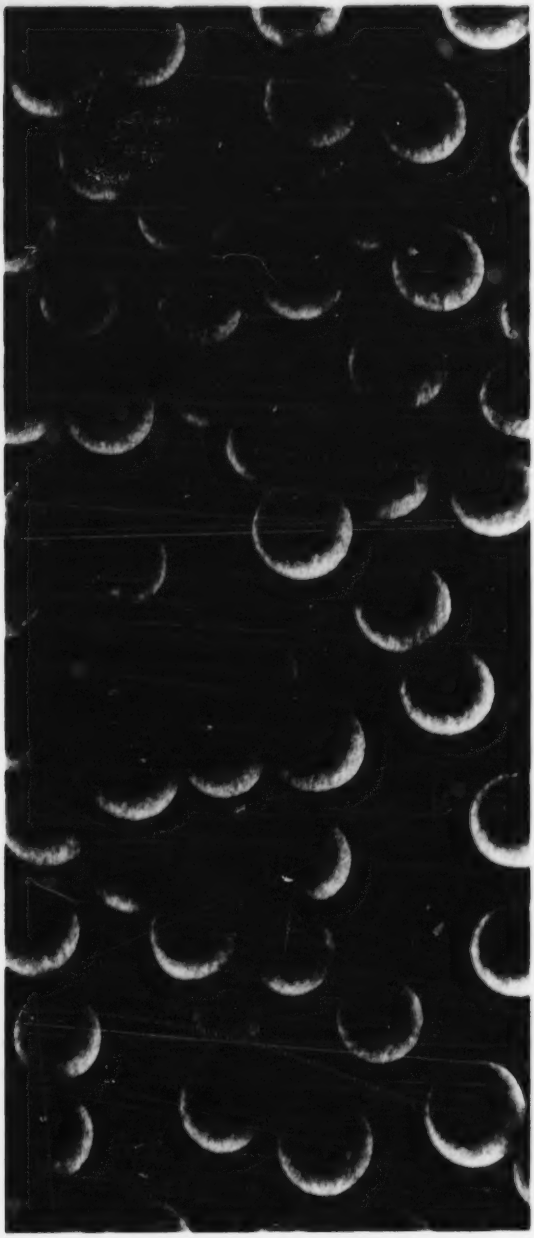
is called *positron emission tomography* (PET). Because positron emitters have short half-lives and must be prepared onsite, PET scans require ready access to a *cyclotron*, a special machine for producing these short-lived radioisotopes. Positron emitters are prepared by irradiating light elements—carbon, nitrogen, oxygen, fluorine—using the cyclotron. With the help of a computer to translate the images captured by the cameras, both SPECT and PET are especially valuable in medical diagnosis. Doctors study the circulatory system and probe the activities of the brain, adding to our understanding of epilepsy, schizophrenia, Parkinson's disease, strokes, Down's syndrome, and Huntington's chorea.

Therapeutic Applications

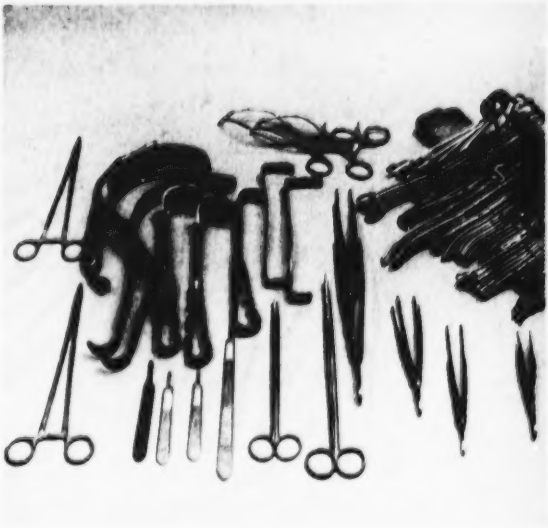
The property of radiation that makes it *dangerous also makes it useful in healing.* When radiation's energy is deposited in living tissue, cells can be damaged or destroyed. For this very reason, radioisotopes play an important role in cancer therapy. Large doses of radiation focused directly on a cancer can destroy it with little damage to surrounding tissue.

Doctors rely on three different techniques to destroy cancer cells with radioisotopes. One approach involves an external machine that destroys the tumor with gamma radiation from a radioisotope such as cobalt-60. Another approach is to place the radioisotope directly into the tumor itself. An innovative example of this approach is the treatment of liver cancer with tiny spheres containing the radioisotope yttrium-90, which lodge in the capillaries of the cancerous tissue, providing a localized dose of radiation. A third approach is to use a radioisotope that naturally concentrates in the diseased organ. This technique is so widely used to treat many thyroid conditions that it has almost replaced thyroid surgery.

An important advance in the radiation treatment of cancer involves radioisotope-labeled *monoclonal antibodies.* Our bodies naturally produce antibodies that attack foreign matter to eliminate it from the body. Recent advances in biotechnology have enabled scientists to manufacture artificial antibodies, called monoclonal antibodies. Artificial antibodies can be genetically engineered to bind to a type of molecule



The radioisotope yttrium-90 is absorbed into tiny manmade resin microspheres that are trapped in cancerous livers, allowing the short-range radiation to destroy nearby cancer cells.



Surgical supplies and instruments are often sterilized with radiation from radioisotopes.

found primarily in a cancerous tumor. Labeled with a radioisotope, the antibody can identify or destroy the cancerous tissue. Monoclonal antibodies labeled with iodine-131 or yttrium-90 are beginning to show promising results for the treatment of cancer.

In addition to their importance in the diagnosis and treatment of diseases, radioisotopes play an important role in the sterilization of medical supplies. Syringes, surgical gloves, and pharmaceuticals like ointments and powders, which might be damaged by conventional methods of sterilization, are routinely treated by radiation from radioisotopes. Other supplies, such as petri dishes, test tubes, and surgical instruments, are also sterilized with radiation.

RADIOISOTOPES IN SCIENCE

Radioisotopes enable scientists to determine the age of the Earth and provide a chronology of prehistoric times. Radioisotopes are helping us unravel the mysteries of our environment, revealing how animal life, earth, air, and water interact with each other. Radioisotopes can also be used to authenticate works of art and even to help solve crimes. As flexible scientific tools, radioisotopes help us increase our knowledge of the world around us.

Geological and Archaeological Applications

Determining the age of the Earth using radioisotopes has radically altered previous concepts of geological history. Early estimates placed the age of the Earth at less than 40 million years. Later calculations using the radioactive decay of natural uranium suggested an age more than ten times this number. More recent radiological calculations set the age of the Earth at 460 million years.

Archaeologists can also determine dates by a technique known as *radiocarbon dating*. Carbon-14 is a naturally occurring, long-lived radioisotope present in all living things. The ratio of carbon-14 to carbon-12 in the atmosphere has been relatively constant throughout history. Because living things take in carbon from the atmosphere, the ratio of carbon-14 to carbon-12 in living things is the same as that in the atmosphere. When an animal or plant dies, it stops taking in carbon, and the amount of carbon-14 in its tissue begins to decrease through the process of radioactive decay. Comparing the

carbon-14-to-carbon-12 ratio in the dead material with the "living ratio" enables us to calculate how long ago the plant or animal lived. This comparison permits us to date fossils that are found in archaeological explorations as belonging to a certain period in history.

Archaeologists collect cane charcoal samples from a Virginia cave. They use carbon-14 dating to determine when prehistoric Indians lived in the vicinity.

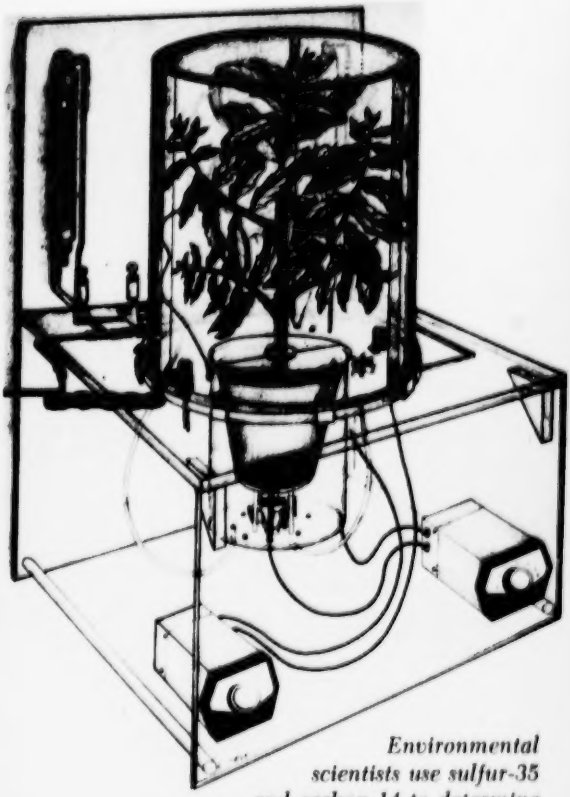
Environmental Applications

In the field of environmental science, radioisotopes assist scientists in exploring the world around us. Radioactive tracers follow materials as they travel through the atmosphere, the waterways, and the food chain and provide scientists with vital information about the delicate balances in nature.

Phosphorus is a plant nutrient found in streams. The addition of a radioisotope of phosphorus (phosphorus-32 or -33, for example) into a stream permits scientists to follow phosphorus up-take and observe how streams react to stressful changes

resulting from high rainfall, heavy leaf fall, and pollutants. Such studies are referred to as *phosphorus spiralling*.

The radioisotope sulfur-35 permits scientists to study the effects of coal run-off and dry-acid deposition on plant life. By injecting sulfur-35 into trees, for instance, scientists are able to determine how trees handle extra sulfur. Measuring the ratio of radioactive sulfur-35 to stable sulfur, scientists have found that some trees send the extra sulfur to their roots, and others seem to throw off the extra sulfur into the atmosphere.



Environmental scientists use sulfur-35 and carbon-14 to determine the effects of pollutants on plant life.

A naturally occurring radioisotope in the Earth's upper atmosphere, beryllium-7, has important applications for environmental studies. Because it is carried to the ground in rainfall, beryllium-7 can be used to help determine the age of sediments in lakes. This process permits environmentalists to determine the settling patterns for a variety of pollutants entering the waterways, thus reducing the number of time-consuming chemical analyses necessary to characterize a sediment.

Scientists at the National Bureau of Standards are using radiocarbon dating to determine the origin of some organic atmospheric contaminants such as methane. By determining the carbon-14-to-carbon-12 ratio, scientists can determine whether a contaminant comes from a living carbon source or a fossil fuel such as gasoline.

Crime Stoppers

Radioisotopes assist investigators with a variety of chemical identification problems in a technique called *activation analysis*. The technique is highly sensitive and can be applied to almost every element on Earth. It is especially useful in identifying trace quantities of materials. Criminal investigations frequently rely on activation analysis to obtain physical evidence for legal purposes. Items such as paint, glass, tape, gunpowder, lead, and poisons can be identified and often connected to crimes. Using this technique, criminologists are able to gather important evidence linking a suspect with a specific crime.

Measurements of natural radioisotopes in this painting proved it to be a forgery.

Activation analysis can also help prove or disprove the authenticity of old paintings by showing whether or not modern materials are present. This and other techniques that rely on radioisotopes are routinely used by museums to spot forgeries and authenticate various works of art.

Activation analysis revealed that Winslow Homer's first version of "Breezing Up" contained ships in different locations before they were moved over to balance the composition. (Courtesy of National Gallery of Art)

RADIOISOTOPES IN INDUSTRY

With radioisotopes, manufacturers detect hidden flaws in hardware and make wear tests on finished materials. Radioisotopes are essential to such remote applications as providing lights for airplane runways in arctic regions and generating electrical energy for a broad range of missions in space. More and more, radioisotopes have become a bridge between the laboratory and industry to improve product quality.

Manufacturing Applications

The application of radioisotopes in manufacturing depends, for the most part, on the fact that radiation loses energy as it passes through substances. Radioisotopes are used to monitor and control thicknesses in the manufacture of plastics, paper, and photographic film. The radiation that passes through the material is measured and compared with the radiation that would pass through a material of the proper thickness. If more radiation is measured, the material is too thin; if less is measured, the material is too thick. Instruments sensitive to the measurements activate controls to maintain the proper thickness. In this way materials can be monitored without being touched.

A portable radiography unit enables an inspector to check for cracks in aged metal pipes.

Radioisotopes also function in gauging devices, controlling everything from the amount of glue on a postage stamp to the amount of sugar in consumer foods.

Another industrial process, called *radiography*, relies on radioisotopes to inspect many types of metals and machines for defects. The process is similar to material inspection with x rays except that the radiation source is portable and the radiation more penetrating. The portable source relies on a radioisotope that has a very penetrating radiation, such as cobalt-60. The portable source is easier to use, suitable for inspecting a wide range of materials, and less expensive than a large machine that would be necessary to produce similar penetrating radiation. Radiography makes it possibie to find invisible cracks and manufacturing flaws in structural materials, welds, and cast metals.

Test-and-Wear Applications

Radioisotopes are used in industry and manufacturing to develop strong and uniform products. For testing, radioisotopes can be added to such products as metal machine parts, tire rubber, and engine oil. Using sensitive radiation detectors, researchers can quickly determine the location and amount of wear that these materials receive. Industry can then manufacture machines and materials that last longer and operate more reliably.

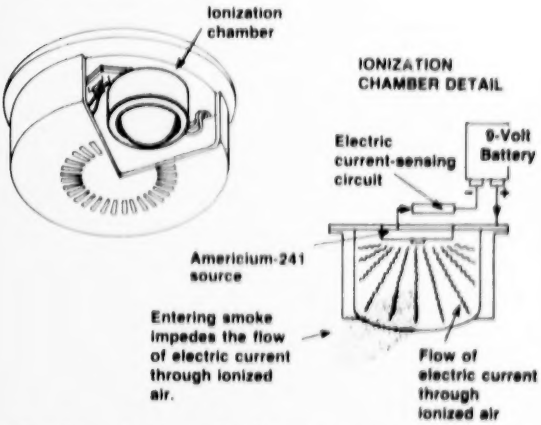
Radiotracers can be added to various solutions that are to be mixed together in manufacturing to permit a ready determination of mixing uniformity. Then, a simple radioactivity test allows the manufacturer to determine when uniformity is reached in the mixing step.

By performing such tests while setting up mixing procedures, manufacturers can be assured of consistant product quality.

Consumer Product Applications

Radioisotopes have a number of applications for consumer goods. They are used to produce the "shrink wrap" film used widely in packaging. First, special film is treated with radiation. Later on, during packaging, the plastic film is heated, which causes it to shrink to fit the shape of the product. Similar processes are used on everything from soft drink bottles to plastic insulation on wires.

Radioisotopes enable antistatic devices in copy machines to keep paper sheets from sticking and lint brushes to eliminate static electricity from clothing. A very important application of radioisotopes in the home is the small amount of americium-241 found in many household smoke detectors. The radioisotope is part of the sensing unit that triggers the alarm when smoke is present.


Ionization chamber
IONIZATION CHAMBER DETAIL
Electric current-sensing circuit
9-Volt Battery
Americium-241 source
Entering smoke impedes the flow of electric current through ionized air.
Flow of electric current through ionized air

Most household smoke detectors use small amounts of americium-241 to trigger an alarm when smoke is present.

Radioluminescence, the light produced using energy released during the radioactive decay process, is an important commercial application of radioisotopes. Luminous watch dials that depended on the natural radioactivity of radium-226 were commonplace years ago. Illuminated *Exit* signs that are powered by tritium serve as reliable safety markers on passenger aircraft, aboard ships, and in many buildings. Emergency lighting on offshore oil rigs and in lifeboats has extended this use of tritium. Since 1984, tritium lights have been used to mark the edges of airport runways at remote communities in Alaska where conventional electric lighting systems are impractical.

Electricity in Small Packages

The heat generated by radioisotopes permits radioisotope-generators to be built to provide electric power for remote applications. In early space missions with flight paths close to the Earth, electrical energy was obtained from lightweight batteries, fuel cells, and solar cells. As missions became more complex and distances increased, the need arose for more compact and longer-lived electrical generators. Electrical generators powered by radioisotopes such as plutonium-238 and strontium-90 fulfill this need.

Radioisotope-powered generators are currently providing electrical energy for a broad range of space missions. These generators have powered our navigational and weather satellites and have been essential in space communications. They allow us to conduct experiments on the Moon and other planets. For the past 20 years, these generators have been providing safe, reliable,

Voyager 2, which passed Uranus on January 24, 1986, draws its power from a radioactive heat source.

and predictable performance in support of our space program efforts. Many of our Nation's outer planetary missions could not have been accomplished without the reliable power provided by these generators.

Here on Earth, generators powered by radioisotopes provide electricity when ordinary electrical sources are not

available. Such generators power weather stations at both the North and South Poles, operate seismic sensing stations in remote locations, and power devices placed on the ocean floor for scientific investigations and national defense.

A U.S. Air Force serviceman installs a tritium light on an Alaskan airstrip.

RADIOISOTOPES AND AGRICULTURE

Radioisotopes have played a role in many improvements in agriculture and hold great promise for the future. Insect infestations have been controlled or eradicated with radioisotopes. Radioisotope tracers in plant nutrients have increased our knowledge of fertilizer utilization, achieving a more economical application of fertilizers. Preservation of food by irradiation is the subject of studies by the U.S. Department of Energy and the U.S. Department of Agriculture. The International Atomic Energy Agency, under charter by the United Nations, also has a number of coordinated programs to preserve foods of interest to developing countries. In a world that produces more than enough food for its inhabitants but where millions still starve, the preservation of food by irradiation may well be the key to a more efficient distribution of food.

Insect Control Applications

Radioisotopes have been used successfully to control insects that destroy crops. The technique offers an alternative to chemical pesticides. In the procedure, thousands of male insect pests are raised in a laboratory and exposed to sterilizing doses of radiation by being placed near a powerful radioisotope such as cobalt-60. This renders the male insects infertile. The sterilized males are then released in an area where insect infestation is a problem. When these insects mate with the females in that area, the eggs produced by the female will not be fertilized and, therefore, will not hatch. Pest populations are then drastically reduced and in some cases completely eliminated.

Screw worm infestation in the Southeastern United States was eliminated by this technique in the middle 1950s. Sterilizing male insects essentially solved the Mediterranean fruit fly infestation in California in the middle seventies. The successful control of mosquitos and flies, such as the tsetse, melon, and horn, has also been demonstrated in various countries throughout the world. Because chemical pesticides are not used, no harmful residues are left on crops, and the approach does not kill beneficial insects.

Farmers in the Southeast successfully eliminated the destructive screw worm without pesticides by using radioisotopes to sterilize the insect pests.

Plant Applications

The addition of radioisotope tracers to chemicals in fertilizers enables scientists to study the nutritional needs of plants. Radiotracers allow us to determine the uptake of chemicals by the plants and the efficiency of fertilization. This knowledge helps the agronomists to raise a better and a greater variety of plants and to make

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more economic use of fertilizers, water, and land resources. Through such means, it has been estimated that the worldwide consumption of fertilizers could be cut in half.

In nature, some plant seeds grow into plants with traits that differ from the parent plant. Some of these new variations improve the plants, and others do not. Historically, people have selected plants with useful traits and cultivated the seeds. Desirable properties including increased yields, improved resistance to disease, better adaptability, and earlier ripening have sometimes been achieved by exposing seeds to radioisotopes. With radioisotopes, researchers are often able to achieve the desired traits faster than is possible using chemical agents or conventional methods of crossbreeding.

One example of an important plant-change induced by radiation is the peppermint plant. The Mitcham variety was the only source of peppermint oil in the United States. When it fell victim to a wilt disease, soil fumigation and crossbreeding techniques yielded plants either still susceptible to the disease or plants with oils that had unsatisfactory flavors. Radiation techniques led to a disease-resistant variety of the plant with properly flavored peppermint oil.

Food Irradiation Applications

One of the most exciting applications of radiation from radioisotopes is the preservation of foods for extended periods of time. Irradiation makes chemical additives and refrigeration unnecessary.

The technique also requires less energy than other food preservation methods. Preserving food by irradiation is under study by the U.S. Department of Agriculture; however, it has been slow to develop in the United States, probably because of the extensive availability of refrigeration and lack of economic incentive and public support. However, the technique is having a great impact abroad, particularly in developing countries where many people do not have enough food to eat, in part, because of food spoilage. The usefulness of food preservation by radiation is best illustrated by our manned space explorations. Astronauts took food sterilized by irradiation to the moon and on shuttle flights. Moreover, they preferred it over all other types of preserved food.

Food is irradiated by exposing it to gamma rays from radioisotopes. Cobalt-60 is the radioisotope in general use, but the Federal government has recently authorized the building of a commercial-type, food-irradiation facility using cesium-137. The radiation process destroys bacteria, viruses, molds, and insects that cause spoilage and disease.

Exposing food to radiation does not make it become radioactive, and its nutritional value is not significantly changed. Irradiating food increases its shelf life, kills insects in grains and stored foods, inhibits the sprouting of vegetables such as potatoes and onions, delays the ripening of certain fruits, and, at the highest doses, completely sterilizes food.

FOODS APPROVED BY FDA FOR IRRADIATION TREATMENT

Food	Purpose	Date Approved
Fruits and vegetables	To slow growth and ripening and to control insects	April 1986
[illegible]	[illegible]	[illegible]
Pork	To control *Trichinella spiralis* (the parasite that causes trichinosis)	July 1985
[illegible]	[illegible]	[illegible]
Wheat, wheat flour	To control insects	Aug. 1963

The U.S. Food and Drug Administration (FDA) has established regulations that approved the gamma radiation of various herbs, spices, natural flavorings, and vegetable seasonings. In 1985, the FDA approved the commercial irradiation of pork to destroy the parasite causing trichinosis. The FDA has proposed standards covering food irradiation practices and irradiated food labeling requirements. Labels will identify such foods and conditions of treatment.

Gamma irradiation of food will not render it unsafe for consumption. A 1984 International Atomic Energy Agency

bulletin states that more than 25 years of testing the wholesomeness of radiation-preserved food throughout the world showed no harmful effects from its consumption. In 1983, the government of Japan sponsored the Asian Regional Cooperative Project on Food Irradiation. Eleven countries participated in the program: Bangladesh, India, Indonesia, Japan, Republic of Korea, Malaysia, Pakistan, Philippines, Sri Lanka, Thailand, and Vietnam. Despite the lack of evidence of any ill affects, the FDA is continuing studies to ensure that all irradiated food is safe to eat.

This symbol is used internationally to indicate foods that are preserved using radiation. The technique, approved for some foods in the United States, does not reduce the nutritional quality of the food.

TODAY AND TOMORROW...

When natural radioactivity was discovered just before the turn of the century, scientists could scarcely have realized the benefits that would be derived from the application of radiation from radioisotopes. Radioisotopes have been present since the beginning of time, but their practical applications are just beginning to emerge. Radioisotopes have improved our methods of diagnosing and treating diseases and powered our explorations of space. With radioisotopes, we can chart the course of events occurring before historical records were kept. With radioisotopes, we can improve our environment, make better industrial products, grow bigger and better plants more economically, and preserve foods in a new way. Scientists now realize that these are only the preview of things to come and that the future holds the promise of many new and innovative ways in which radioisotopes can improve our lives.

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